Evaluation of Direct Electrochemical Conversion of Carbon Anode Fuels in Molten Carbonate Electrolyte in a Novel Configuration

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The direct electrochemical conversion of carbon to electricity involves discharge of suspensions of reactive carbon against an oxygen (air) cathode. The free energy and the enthalpy of the oxidation reaction are nearly identical, allowing theoretical efficiencies ($\Delta G/\Delta H$) approaching 100% and consequently low thermal loads. The activities of the elemental carbon and of the carbon dioxide product are invariant. This stabilizes cell EMF and allows high fuel utilization in a single pass.

We report new data on the electrochemical behavior of carbon materials derived from methane, petroleum, coal, petroleum coke and biomass in an electrochemical cell using a molten salt electrolyte. The carbon anodes consist of slurries of finely-divided carbons in a molten carbonate melts (in particular, the $(Li,K)_2CO_3$ eutectic, melting at 488 °C). The cell separator is a wetted porous ceramic material. More than an order of magnitude difference in reactivity is found between different carbon fuels. In these experiments, the cathode reaction gas is a mixture of carbon dioxide and air, while the anode atmosphere is a combination of inert gas and CO_2.

Cathode: $O_2 + 2CO_2 + 4e^- = 2CO_3^{2-}$
Anode: $C + 2CO_3^{2-} = 3CO_2 + 4e^-$
Total Reaction: $C + O_2 = CO_2$

Nickel, gold or stainless steel porous current collectors are used at the anode and cathode. At temperatures of 550-850 °C, cell voltages of 0.8-0.9 V are reported at current densities of 10-100 mA/cm^2. Open circuit potentials of over 1 V are reported.

Turbostratic carbons with high specific surface area show high reactivity. These fuels may be derived from a range of sources, including biomass, petroleum and coal.

A novel configuration is reported here that allows continuous refueling under load and that regulates wetting of fuel and electrodes. Applications include base load utility power generation and carbon/oxygen primary batteries.

ACKNOWLEDGEMENTS

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. We gratefully acknowledge the LLNL Laboratory Directed Research and Development Office for funding.